SAL(06)4

Plan for Workpackage 3 of SALSEA

1. Why should we study salmon in the sea?

Atlantic salmon stocks have declined in both Europe and North America and all evidence points to there having been changes in the ocean phase. Evidence includes:

- Decreasing trends in overall production of salmon suggesting that many stocks have been affected by the same factor(s);
- Decreasing trends in marine survival (smolt to adult) despite fishery closures;
- Adult returns have declined in some areas despite there being no decrease in smolt production.

At present we are unable to isolate where in the ocean these changes have occurred, but various observations suggests that they may be associated with factors operating in particular oceanic areas or at particular times. For example:

- Numbers of MSW salmon have declined more rapidly than numbers of 1SW fish in both North America and Europe;
- Southern stocks have declined more rapidly than northern stocks in both North America and Europe;
- North American stocks have declined more steeply than European stocks;
- Models indicate a drop in productivity (i.e. how many adult offspring are produced per spawner) of North American stocks around 1990.

Many of the problems that might have accounted for the decline in stocks have been eliminated, or have been/are being addressed, including:

- Freshwater pressures, including obstructions, habitat degradation and water contamination, are being addressed by habitat protection and restoration programmes;
- Potential post-smolt by-catch in the Norwegian Sea has been investigated and probably eliminated as a major cause of mortality;
- Fishery management issues have been addressed and methods put in place to limit exploitation; most directed fisheries have been controlled or eliminated – e.g. distant waters fisheries and many homewater mixed stock fisheries.

The main outstanding problem is related to factors at sea, which is why marine research is urgently required. Such research is not only required to help to identify the problems facing salmon stocks themselves, but salmon may act as a 'marine canary' and be indicators of changing marine conditions. This is because:

- Salmon generation time is short (one to three years in marine waters) relative to other species, so they integrate conditions within each year (many marine species take longer to mature) and provide immediate indices of changes in marine conditions;
- Salmon migrate over long distances so they integrate conditions over large areas.

2. What do we know about the marine ecology of salmon?

Current knowledge on the distribution and migrations of salmon in the sea has been derived from commercial fisheries (West Greenland, Faroes, Norwegian Sea) and limited numbers of research surveys, which have principally been undertaken in the Norwegian Sea, Labrador Sea and the Gulf of Maine. These surveys and fisheries have also permitted limited sampling of fish at different stages in their marine migrations, but this sampling has not previously been undertaken in a co-ordinated fashion. While this has been sufficient to provide a coarse picture of the origins and movements of salmon at sea, there remain significant gaps in our knowledge (Table 1 and Figure 1).

Table 1. Current knowledge of the distribution and movements of salmon in the sea (see also Figure 1).

Southern European	Smolt		Post-smolt							1SW salmon											2SW salmon				
	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	April	May
Estuaries																										
North Sea / Cont. Shelf																										
Faroes / Norwegian Sea			?			?							?	?	?		?	?								
Northern Norwegian Sea			?		?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?		
Barents Sea																										
Greenland Sea						?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?		
Iceland Sea					?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?		
Iceland Basin					?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?		
Irminger Sea							?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?		
West Greenland																?					?	?				
Labrador Sea																										

Northern European	Smolt		Post-smolt							1SW salmon											2SW salmon				
	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	April	May
Estuaries														?						?	?	?	?	?	?	
Inshore														?						?	?	?	?	?	?	
Faroes / Norwegian Sea			?			?							?	?	?		?	?							?	?
Northern Norwegian Sea					?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?		
Barents Sea							?	?	?	?	?	?														
Greenland Sea							?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Iceland Sea								?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Iceland Basin								?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Irminger Sea							?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	
West Greenland																?					?	?	?	?	?	
Labrador Sea																										

North American	Smolt		Post-smolt							1SW salmon											2SW salmon				
	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	April	May
Estuaries													?							?				?	
Inshore													?							?				?	
Atlantic coast NS	?						?	?	?	?	?	?	?							?					?	
Gulf of St. Lawrence								?	?	?	?	?	?							?	?	?	?	?	?	
Grand Bank				?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Labrador Sea				?				?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	
West Greenland											?	?	?	?	?	?					?	?	?	?	?	?
Irminger Sea											?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Norwegian Sea / Faroes																							?	?		

Not found there
Found there
? Don't know

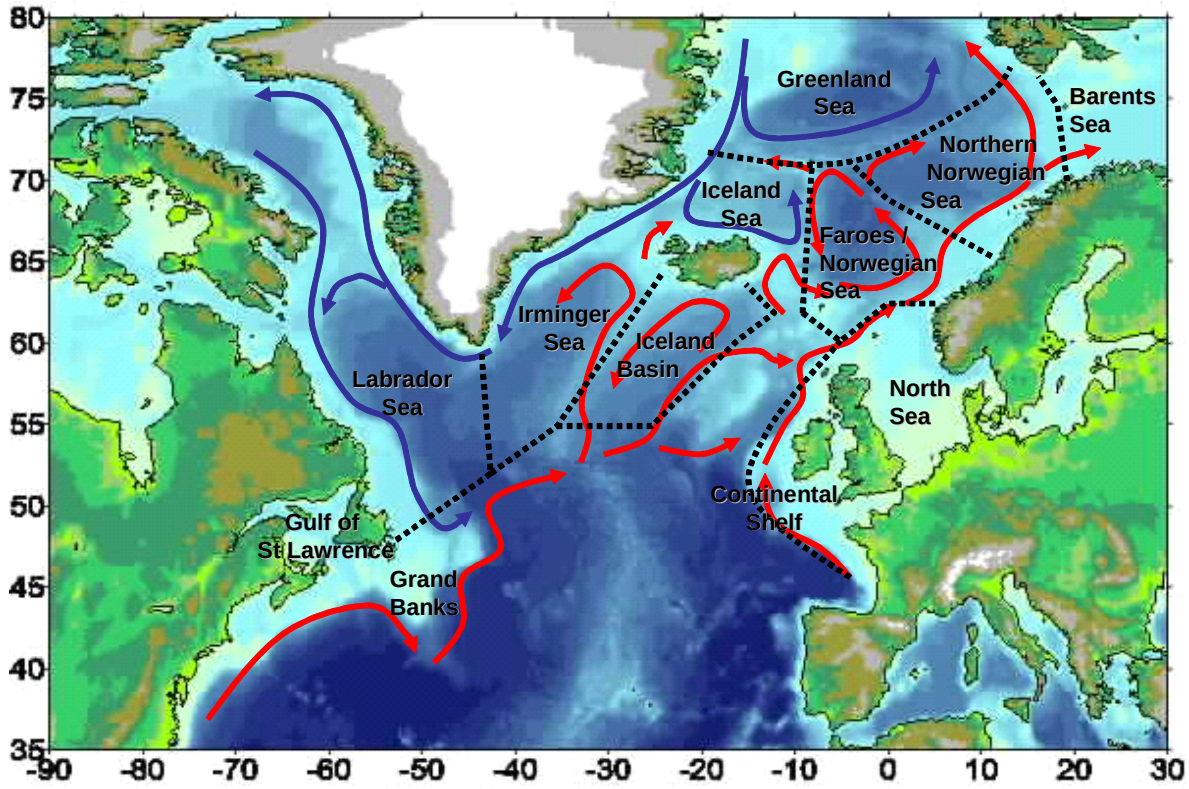

Figure 1. Areas and currents in the North Atlantic (see Table 1)

Previous research provides clues at to what may be driving marine mortality:

- Mortality is expected to be highest when fish are smallest (i.e. first few months after emigration) so emigration in coastal waters may be critical;
- Common patterns of decline in widely separated stocks suggest problems where fish co-occur;
- Survival at sea appears linked to post-smolt growth;
- Condition of salmon is known to vary between years (e.g. years of thin grilse) and some salmon show signs of growth checks (on scales) in first sea year in some years;
- Southern European and North American stock co-occur at West Greenland as 1SW fish;
- European salmon are most widely distributed as 1SW fish (i.e. Greenland to homewaters);
- Abundance and time of return of salmon varies (e.g. poor runs may also be late or small fish);
- Salmon stocks have been declining while other pelagic stocks (e.g. herring) are doing well.

3. <u>What key things don't we know about salmon in the sea?</u>

There remain a large number of knowledge gaps about salmon in the sea. Obtaining information in any of these areas will assist in determining why stocks have been declining and whether management action can be taken to mitigate the problem. Areas where our knowledge is limited include:

- When, where, why or how salmon are dying at sea;

- Distribution, migration and survival of smolts from emigration through estuaries to first summer at sea;
- Location of European salmon during first winter;
- Location of Northern European salmon between their emigration from coastal waters to the time of homing migrations through the Norwegian Sea;
- Relative location of stocks in the sea that are doing well compared to those doing badly;
- Where and when maturing and non-maturing 1SW fish separate and what determines the decision to mature;
- Environmental preferences (e.g. temp) at different life stages;
- Shoaling behaviour – i.e. interdependence of fish;
- Migration mechanisms for navigation from home rivers to open ocean, and return;
- Roles of salmon in pelagic ecosystems (probably small);
- Relationship between the distribution of salmon and their prey;
- Factors affecting fitness and fitness criteria.

4. Why is a co-ordinated marine research programme required?

The benefits of working together in a collaborative programme include:

- More efficient sharing of facilities and pooling expertise;
- Ability to co-ordinate surveys in time and space;
- Make best use of existing information;
- Sum is greater than parts.

Clearly the SALSEA programme is not able to investigate all potential issues relating to the mortality of salmon in the sea in all areas. Since the major problems appear to be facing large groups of stocks, the survey programme will concentrate upon areas where stocks from many rivers are thought to be present at the same time. Factors that may be affecting a small group of stocks in a specific area will need to be addressed by local studies.

International collaboration also increases the possibilities of linking the marine research programme to other areas of marine research. Other programmes that are ongoing and may link to SALSEA include:

- Continuous Plankton Recorder run by SAHFOS, Plymouth
- Argo programme to deploy environmental drifters for the collection of oceanographic data;
- International Polar Year (2007) will have a number of vessels in the northern oceans;
- Satellite data (environnemental, productivity, etc) ;
- Marine fisheries surveys which are undertaken routinely in many areas;
- EU R&D Proposal – "CoastTrack": proposal for arrays of acoustic receivers in coastal waters;
- EU R&D Proposal – "ICARUS" - Impacts of climate change on sustainability of wild and farmed anadromous fish stocks.

5. What survey techniques will be used?

A range of approaches may be used to survey salmon stocks in the sea, investigate the behaviour of individual fish and collect ancillary information, including:

- Surface rigged pelagic trawl with single or paired vessels;

- Pelagic trawl with live capture box;
- Pelagic trawl with video (non-capture) cod-end;
- Long-lines;
- Drift nets;
- Tracking using acoustic tags;
- Tagging with pop-up or archival tags (DSTs).

Each of these methods has strengths and weaknesses in providing the required information on salmon in the sea. For example, normal fishing methods (trawls, long-lines etc) will be required to catch salmon for sampling, but video trawls may permit more continuous, and thus more comprehensive, surveying of relative abundance. Pair trawling is likely to provide higher catch rates with surface trawls than use of a single vessel. Long-lines and drift nets may be needed when larger salmon (1SW+) are the expected target because towed trawls appear to under-sample larger salmon. As a result different combinations of methods may be used in different surveys. Different fishing methods will also be required to collect information on prey species or macroplankton.

Additional relevant information on the marine habitat of salmon may be gathered, including:

- Environmental measurements using continuous recording, spot sampling, and satellites;
- Plankton sampling using bongo-nets, Gulf-7, CPR type samplers, acoustic plankton assessment or macroplankton trawls.

6. What data will be collected from captured fish and how will they be used?

The determination of the river/area of origin of salmon captured in the surveys is a priority task of SALSEA. Baseline data are currently being collected to allow Genetic Stock Identification of the majority of samples. All the data on fish caught during the surveys will be analysed relative to the origin of the fish and to characteristics of the survivors of these stocks one to several years later. The marine program should therefore be closely linked to homewater monitoring and research programs.

Catches of post-smolts and older aged fish will provide information on distribution and relative abundance of salmon. These will be related to geographic (latitude, longitude) and oceanographic (fronts, temperature, salinity) characteristics. These data will provide information on preferences and/or selection of the physical characteristics by size / age groups. Catches and relative abundance of other species, including macroplankton aggregations, will provide information on the distribution of salmon within this larger pelagic ecosystem.

Salmon which are captured in the surveys will be sacrificed and autopsied to quantify life history characteristics which have been hypothesized to relate to survival (Table 2). Minimally, comparisons will be made between fish originating from northern and southern areas as these two groups differ in survival rates and trends in the rates over time. Specifically, the questions asked will include:

- Does early marine growth as inferred from intercirculi spacing of scales differ between southern and northern stocks?
- Does early marine growth (intercirculi spacing) differ between postsmolts and those surviving to home rivers one to two years later?

- Does condition of fish (lipid levels) differ among northern and southern stocks?
- Are fish from different stocks and different areas feeding on different prey which may affect the condition of the fish as they enter their first winter?
- Do disease and parasite characteristics differ between stocks and stock areas?
- Do salmon from southern areas and stocks within these areas differ in heavy metal and organic compound loads from fish originating in other areas?

7. Where and when should surveys be conducted?

Fish emigrate from Southern European rivers between March and May. Some tagged individuals have subsequently been caught in *ad hoc* surveys conducted in the Norwegian Sea during June and July. These observations are consistent with the smolts migrating along the shelf edge and orienting themselves with the shelf edge current (Figure 1). Assuming that smolts emigrating from other rivers behave in a similar way, it appears likely that post-smolts originating from both southern and northern Europe rivers pass through the Norwegian Sea between June and August. The relative timing of these movements, which may be influenced by such factors as the size of the smolts and their precise emigration time, may be indicative of their subsequent migration patterns and point to factors causing differential levels of mortality. Post-smolts from northern Norway, on the other hand may remain to the north of these areas but mix with southern European stocks in the Northern Norwegian Sea later in the summer. If post-smolts from Finnish and Russian rivers exhibit similar behaviour they may remain in the Barents Sea throughout the summer.

The first survey programme will therefore be based around conducting repeat survey transects in the Norwegian Sea, Northern Norwegian Sea and Barents Sea to provide the means to validate these modelled distributions and further investigate differences between these stocks which may account for differences in marine survival. The surveys will use a combination of capture and video pair-trawls.

Similar hypotheses may be developed for the movements of post-smolts originating from US and Canadian rivers in the North-West Atlantic. A second parallel survey programme of repeat survey transects will therefore be developed to be undertaken on the Grand banks and southern Labrador Sea.

Very little is known about the whereabouts of non-maturing 1SW salmon in the sea. Less than half the Southern European fish of this age migrate as far as West Greenland and very few of those from Northern Europe go to West Greenland. It appears possible that these fish simply fall short of the waters to the west of Greenland and remain in the productive feeding areas of the Irminger Sea. While a greater proportion of North American non-maturing 1SW salmon are thought to go to West Greenland, some are known to have been caught on the east Greenland coast suggesting that they also may feed in the Irminger Sea. A third survey programme will therefore investigate the occurrence of salmon in the Irminger Sea; this survey will first employ trawls/video-trawls to locate salmon but may then use a combination of methods (pair trawl, long-line, drift-nets) to sample them, depending on the size of the fish found.

As a further survey programme, it also proposed that sampling in the west Greenland fishery could be enhanced to improve the nature and extent of the programme and to integrate it with research in other areas.

Table 2 Specific information to be collected from captured and sacrificed fish

Rank	Characteristic	Data or tissue	Equipment	Laboratory for processing	Why?
1	External characteristics	Length, weight whole/gutted, adipose clip, tags, CWT, sex wild/farmed, sea lice	Measuring board, balances, CWT detector	Any and all	Basic biological characteristics data
1	Stock origin	Fin clips, fin or opercula punches, adipose fin, scales	Vials with tissue preservative	To be determined	It is essential that fish captured at sea be identified as to their river/region of origin
1	Determination of age and growth characteristics	Scales from standard location	Forceps, envelopes, dry storage	Any and all	River age, sea age, intercirculi spacings to quantify growth rate at different stages. To be compared with adult survivors of those stocks to test hypothesis of growth-mediated survival
1	Feeding	Stomach contents	Jars, formaldehyde	To be determined	Basic information to describe prey relative to size of salmon, location captured, period captured
1	Condition (using lipid content)	Muscle, viscera tissue	Plastic bags, frozen	Process for relative lipid content	Energy reserves may determine age at maturity and ability to survive, as well as describe previous feeding history
1	Indicators of ocean distribution, elemental analysis	Otoliths, scales	Dry	To be determined	Variability in elemental composition reflects ocean chemistry in which salmon are distributed and grow. Comparisons among stocks.
2	Potential sea age at maturity (females)	Ovarian tissue	Cassettes, Bouin's fixative	Gulf Fisheries Centre (Canada?)	Work on Canadian populations has shown that oocyte development in the ovaries of smolts differs between grilse stocks and MSW stocks. This will provide information on potential age at maturity of sampled females
2	Trophic ecology (stable isotope signatures of carbon and nitrogen - ^{13}C & ^{15}N)	Scales, muscle, adipose clips	Dry for scales, frozen for tissue	Universities in Canada	Salmon are opportunistic feeders, targeting prey of different trophic levels as they grow. Stable isotope signatures are an integration of recent feeding history
3	Viral and bacterial	Blood sample using kidney smears	Refrigerated	DFO Canada (?)	Pathogen characteristics may differ among stocks and my induce differences in survival
3	Parasite abundance and diversity	Carcasses	Frozen	To be determined	Parasites may reflect origin and depending on type and abundance may induce differences in survival
4	Heavy metal, pollutant loads	Muscle fillet	Frozen	To be determined	Heavy metal and organic pollutant loads may differ among stocks and affect growth and survival
4	Physiological growth profiles using RNA/DNA ratio	Muscle tissue	Frozen	To be determined	Provides a measure of current growth rate
4	Hormone levels to assess state of maturity	Blood samples	Frozen	To be determined	Can it be used to assess maturing versus non-maturing fish at early stages?

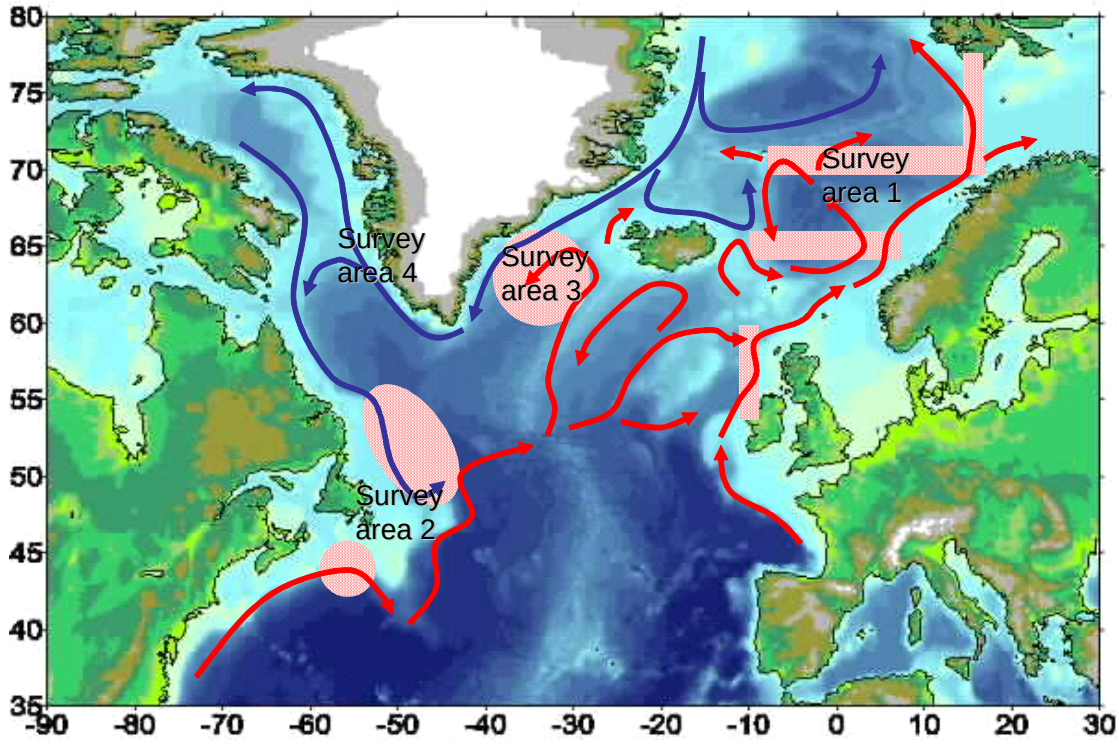

Figure 2. Location of proposed survey programmes in the North Atlantic

The proposed survey programme is therefore as follows:

Survey programme 1: Norwegian Sea Post-smolt surveys:

Survey 1a: One vessel (or pair) undertaking repeat transects for about 30 days in July at 65degN from shelf edge to north of Faroes, plus additional transects to north and south.

Survey 1b: One vessel (or pair) undertaking repeat transects for about 30 days in July/August at 70degN from shelf edge to north of Faroes, plus additional transects to north and south.

Survey 1c: One vessel (or pair) undertaking repeat transects for about 30 days in August along 15degE longitude from Norwegian shelf edge to Spitzberg, plus additional transects to east and west.

Survey 1d: One vessel (or pair) undertaking repeat transects on the shelf edge to the west of Ireland/Scotland.

Aims:

- Test whether distribution of post-smolts matches that predicted from migration models
- Repeat transects providing description of movement of identified stocks through the survey area

- Characterising early marine growth of identified stocks
- Explore movements on fronts compared with main currents
- Investigate co-occurrence of species in ecosystem context
- Investigate changes and differences in biological information (e.g. condition, trophic levels of diet, …) of post-smolts at different locations and times, including comparison among and within stocks
- Describe distribution of post-smolts in relation to biotic and abiotic conditions.

Survey programme 2: Northwest Atlantics Post-smolt surveys

Survey 2a: One vessel (or pair) undertaking repeat transects in for post-smolts for about 30 days in the Labrador Sea

Survey 2b: One vessel (or pair) undertaking repeat transects for post-smolts for about 30 days on the Grand Banks

Aims:

- As described above for European stocks

Survey programme 3: Distribution of salmon in the Irminger Sea.

Survey 3: One vessel (or pair) undertaking survey transects between about 60-65degN for about 30 days off the east coast of Greenland. Exploratory fishing for larger fish may need different methods such as pair trawling, or video trawls operating at higher speed.

Aims:

- Describe composition of salmon stocks in the region (may include non-maturing 1SW fish from Southern European, some of which may be on their way to West Greenland; North American fish; Northern European fish that don't migrate as far as West Greenland; and Iceland post-smolts)
- Provide data to support development of migration models
- Identify stock-specific maturity status

Survey programme 4: Expanded West Greenland sampling programme

Survey 4: Increased sampling of catches in West Greenland coastal fishery, or chartering of local fishermen

Aims:

- To enable more comprehensive sampling of the salmon migrating to the west coast of Greenland.
- Provides an opportunity to collect data on same cohorts of salmon as sampled in earlier programmes on post-smolts and subsequently on their return to homewaters
- Parallel sampling to be undertaken on smolts leaving and adults returning to freshwater.

8. What vessels would be used?

The above programme sets out the desired cruises and assumes that vessels will be fully available. That situation could be achieved by chartering vessels or by a mixture of charters and national research vessels. Some national research vessel time is expected to be available, but there may be difficulties in obtaining such vessels for the precise times and/or durations proposed. Charters would depend entirely on raising the necessary funds, as would the provision of some national research vessels, but such funds may or may not be forthcoming. There may be advantages in chartering fishing vessels for some surveys where particular methods are to be employed, and such vessels may be cheaper and make better use of available time, given probable shorter distances to travel from port.

So, the actual situation will not be known until fundraising has progressed further. The above programme is best seen as a "wish list" which can be partially or completely achieved depending on the extent of national research vessel availability and on success in fundraising which would allow chartering

9. Other possible survey issues

A range of additional issues will need to be considered, some in discussion with national authorities, including:

- permissions required for fishing in national or international waters;
- authorisation required to take quota species as by-catch;
- risks of catching protected species.